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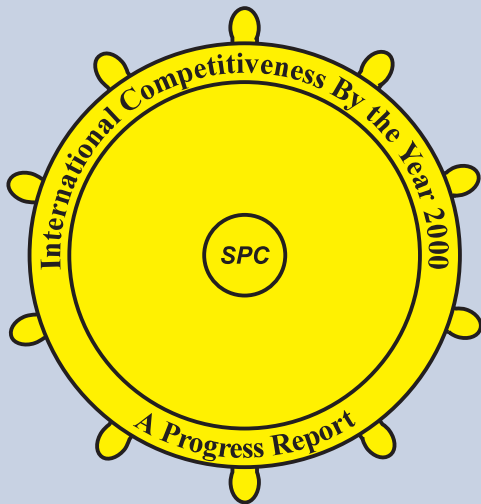
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Shipyard Technology Development Strategies

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ABSTRACT

Effective development strategies for shipyards need to recognize the different economic and technological environments in which individual organizations operate. The benefits of implementing a given technology will vary according to the different cost structure, labor market and technological development of the individual shipyard. Specifically, capital investments in expensive hardware, can lead to a deterioration of the overall performance of the business, whereas improvement in the organization and practices of the business may produce improved performance from the existing hardware and facilities. Development strategies must be targeted towards quantifiable improvements against the needs of the market or competition and must recognize the impact of different technologies on the performance of the particular yard. This paper looks at the issues involved and appraisal techniques to support effective investment in hard and soft technological developments

NOMENCLATURE

AWES	Association of West European Shipbuilders
CGT	Compensated Gross Ton
EY	Employee Year
GT	Gross Ton
JSA	Japanese Shipbuilding Association
UK	United Kingdom
US	United States of America

INTRODUCTION

The intrinsic mobility of ships forces shipyards to compete for their customers in an international market place. It matters little to the purchaser whether the vessel ordered is built in Northern Europe, the Americas, or the Far East, provided that the stipulated price, delivery, reliability and operational objectives are met. The diversity of economies in which shipyards operate, however, ensures that there are substantial differences in many aspects of their operating characteristics. The global nature of the market, therefore, results in a composition in which not only are the adversaries of contrasting statures, but are playing on a field that is far from flat. Thus the adoption of the correct strategy for a yard is critical to obtain an effective use of investment funds and the right balance between hard and soft technology to achieve a competitive cost per unit output.

Development is a means of transition from one state at some point in time through to some future state. The potential pace of development is related to the development and adoption of technology in general.

Shipyards use elements of the available technology and adopt them to improve productivity and ultimately performance

[1].

The level of technology adopted at any time depends on the following:

- the technology available,
- the technology approved for use, and
- the cost structure of the yard.

That is, as labor rates increase and the cost per unit output increases then investment in technology could be justified on a Return on Investment basis. Typically for a shipyard the payback period is dependent on the time scale of the present order book and the number of workers displaced by the technology implementation. Consequently, different shipyards with different cost structures can justify the adoption of different technologies at different times (see Figure 1). As available technology is approved for shipyard use then those yards that have a high labor cost base tend to adopt it sooner. Yards with a lower labor cost base will lag behind creating a technology gap.

A good example of this is laser welding. The technology to undertake laser welding has been developed over the last 10 to 15 years [2], whereas approval by classification societies its the limited use is only now becoming available. The higher labor cost yards are looking for rapid adoption because of the reduction in distortion it offers which is fairly labor intensive to remove.

The most efficient yards tend to make these decisions with the aim of obtaining a cost advantage rather than a technology lead. Other yards adopt a strategy whereby closing the technology gap tends to dominate the strategy often leaving the yards as low labor cost but high unit cost facilities.

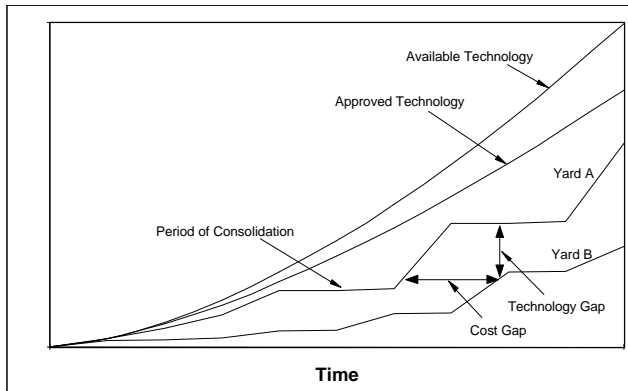


Figure 1 Patterns of Shipyard development in relation to available technology

Clearly, as labor costs increase through development of the local economy, there will be opportunities to justify a transition from one level of technology to another, where the periods between developments are periods of consolidation.

Technology itself has two aspects the hard and the soft aspects. Hard technology refers to the physical tools and equipment (hardware) required to design and build ships in a shipyard such as welding equipment, robots, CAD-CAM, etc. Soft technology refers to the management, organization and procedures that are in place to maximize the use of existing facilities and human resources, procedures, processes and systems for functions such as planning, quality control, cost control, material control, education and training, etc.

A technology development strategy for a shipyard must therefore consider its current level of competitiveness and the present performance of its hard and soft technologies. If the performance of the soft aspects is good then the maximum benefit is being obtained from the existing facilities and further prudent hardware investment would tend to reduce cost per unit output. However if performance of the systems and management processes is inadequate then there is a temptation to 'buy the shipyard out of trouble' by investing in ever more up to date hardware, but this tends to actually increase the cost per unit output.

In order to identify useful development strategies for a given yard, it is necessary to establish its competitive position. This task is complicated by the global context of the industry and the resulting variety of shipbuilding enterprises, but benchmarking procedures have been developed [3] which enable the effectiveness of the work processes of a given yard to be compared with that of others. In particular benchmarking allows the discrepancy between an individual yard's position and that of the worlds best to be identified. Individual yards can also be evaluated in a second way, by undertaking a technology audit. This quantifies the level of technology employed by the yard, and is therefore an important indicator of its performance capability. In the first part of this paper both these established tools are outlined, while in the body of the paper the application of these concepts is discussed. This is shown to provide insights

into the relevance of alternative development strategies that could be adopted by individual yards in order to improve their position in the international market for ships.

COMPETITIVE BENCHMARKING

Benchmarking requires an agreed measure which can be evaluated for every company in order to compare an individual company's performance with that of the company which is recognizably the best. The general approach now in use by the industry consists of two elements to measure:

- **cost competitiveness** - a measure of cost per unit output, and
- **technological sophistication** - a measure of the aggregate level of hard and soft technology adopted.

These measures allow shipbuilders to compare their current performance with that of competitors and to set targets to be achieved as part of the strategic objectives for the business. These two measures have become the shipbuilding industry standard for comparison and thus can provide a basis upon which individual yards can base a development strategy to underpin the achievement of strategic performance targets.

Cost competitiveness

In the commercially competitive world of shipbuilding a measure of cost per unit output indicates a company's effectiveness [4]. This approach is now well established since its first use by Appledore International [5] and has been used for a number of studies. A summary is provided here for completeness.

Using the calculated costs and output a simple, but effective, comparison of the performance of different yards can be made in terms of cost per unit of output. In calculating the cost and output for a given yard it is advisable to collect data over an extended period of perhaps three years, in order to average out the effects of work in progress. As the benchmark comparisons are intended to be internationally applicable the costs are calculated in US dollars (although exchange rate movements should be borne in mind as they make an analysis time dependent).

Costs As benchmarking is concerned with the effectiveness of the company's procedures (i.e. in adding value to the raw material inputs), the costs should exclude those for the direct materials attributed to specific contracts and concentrate on the added value (i.e. the remainder making up the total operating costs for the company). This is calculated by summing the following totals:

- wages paid to all employees, including overtime and bonuses,
- costs for all subcontractors,
- social costs of employing workers,
- costs of materials and services to run the business (not chargeable to specific contracts),
- overhead costs, and

- cost of supply-and-fit type subcontracted items.

Output Shipyards produce a wide range of vessels which vary both in size and in complexity of construction. The traditional measure of output has been the steel weight of the vessels produced, but this does not take account of the higher work content necessary for vessels which are more complex to build. Other measures of output, such as total deadweight, or total Gross Tonnage (GT) are no better in this respect. Collaboration between the Association of West European Shipbuilders (AWES) and the Japanese Shipbuilding Association (JSA) resulted in the Compensated Gross Ton (CGT) as an international measure of output [6]. For any ship this is established by multiplying the GT by a coefficient which reflects the amount of work necessary to produce that particular type and size of ship. The latest figures used for the CGT coefficients were produced jointly by the Organization for Economic Co-operation and Development, AWES and JSA [7].

Cost curves Performance presented simply as \$ per CGT however fails to indicate the qualitative difference between shipyards operating in high or low wage economies. For a given shipyard, the wage levels are predominantly an external factor beyond the control of the business and as such represent a constraint rather than a controllable variable.

This issue can be addressed if the measure is disaggregated into two component elements, and data collected accordingly, namely:

- cost per employee year, and
- employee years per CGT.

Clearly the product of these two functions results in the same benchmark measure of cost in \$ per CGT, but allows the information to be presented in a more revealing way, as shown in Figure 2. On this chart the vertical axis is employee years per CGT, the horizontal axis is cost in \$ per employee year and the curves represent a series of iso-cost lines for a range of cost per unit of output values. Any given yard can be plotted as a discrete point on the chart and will lie on the cost curve representing its own performance. The bold line indicates the current international benchmark, which is a best performance of around \$800 per CGT.

On Figure 2 two hypothetical shipyards are shown which are achieving this benchmark performance under different conditions. By presenting the performance in this way it can be seen that yard A is a low cost and low productivity yard, while yard B is high cost and high productivity. Yard A is operating in a low wage economy with procedures which are labor intensive and use little automation, in contrast yard B is operating in a high wage economy where the more expensive labor costs would be offset by increased productivity. Yards which appear above this benchmark line, on cost curves representing higher cost per unit of output, are not operating competitively, and should look to improve their performance to become competitive. In improving their performance they will progressively move onto lower cost curves until they reach the benchmark value and then drive the benchmark lower as they become market leaders.

Initially this approach concentrated on the merchant shipbuilding sector covered by the CGT coefficients. However such techniques have now been successfully applied in naval shipbuilding [8].

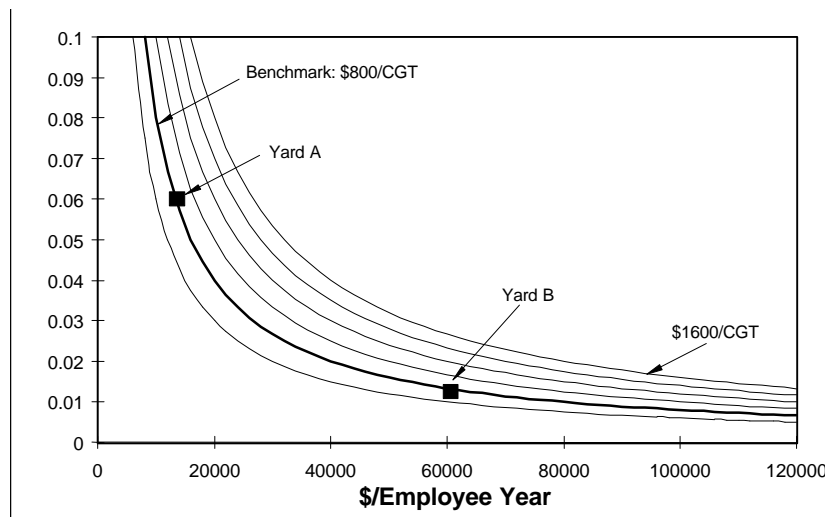


Figure 2 Global shipyard competitiveness presented on cost curves

Technological Sophistication

A comparison of the technological sophistication of shipbuilding yards can be undertaken through technology audits [9] thus evaluating the business through a different perspective. The audit does not assess the actual performance of a yard, but rather establishes the potential capability of a yard as a result of its investment in technology. The audit is undertaken by examining a series of specific elements in the shipbuilding procedure and rating these on a technology scale set from 1 to 5.

The full audit considers 72 basic elements, these being subdivided into 8 audit modules, covering both the hard (e.g. machinery and equipment) and soft (e.g. management and operational systems) aspects of technology. The resulting assessment of a yard's technological position can then be presented as a technology profile in the form of a bar chart. This can be done for the individual audit modules, or for the weighted average value of all the audit modules to show the position of the yard as a whole.

The five technology levels used in the audit reflect the state of technological development of the most advanced yards over the past 30 years.

- **Level 1** is that of shipyard practices in the 60s, with several berths serviced by small cranes. There is little mechanization, and outfitting is largely carried out on board ship after launch.
- **Level 2** reflects best practice of the early 70s, with fewer docks, larger cranes, and some mechanization. Computers are used for some operating systems.
- **Level 3** is the stage first achieved in the late 70s in new or fully redeveloped shipyards in the US, Europe, and Japan. A single dock is serviced by large cranes with some environmental protection. There is a large degree of mechanization and the use of computers.
- **Level 4** is the technology of the late 80s with a single well protected dock, with fully developed operating systems and extensive early outfitting.
- **Level 5** is the current state of the art with automation in some areas, and extensively integrated operating systems using CAD/CAM. It is characterized by efficient computer aided materials control and effective quality systems.

These five levels of technology are used to describe an entire yard, but similar descriptors have been established for each of the audit modules, and for the basic elements in each module.

In interpreting the audit results, it should be recognized that higher levels of technology are not intrinsically better, as high technology implies high capital cost which may be inappropriate in a low wage economy. It is widely recognized however that an even level of technology is important, so efforts should be made to avoid having elements of high technology which are isolated in an environment of lower technology.

Development strategies based on the technology audit will seek to raise those elements of the technology profile which are falling behind a yard's overall level, and then to raise the overall level in a uniform way.

EFFECTIVE TECHNOLOGICAL DEVELOPMENT

The benchmarking tools described above provide managers with two perspectives on the business through which to establish the extent and direction of the development strategy appropriate to their business. The cost curve approach provides suitable targets for an improvement strategy based on a comparison between the performance of different yards, while the technology audit exercise identifies what technology investment options exist and where such investment should be targeted.

In a commercial environment, an effective strategy seeks to reduce the cost per unit of output relevant to the market sector in which a company wishes to operate to a level which:

- is lower than the current market revenue level; and
- establishes market leadership.

Technology is a means to achieving this rather than an end in its own right however this seems to have been overlooked by yards when initiating development programs. This has resulted in inappropriate investment in technology and/or ineffective implementation of the technology. To make matters worse, decision making processes are often distorted by conventional accounting practices, and too often a financial accounting perspective provides an inadequate or even misleading basis on which to evaluate potential developments. The key to avoiding this is improved understanding of the business, what the measures mean, and the effect of alternative strategies.

The following part of this paper looks at techniques that build on the two basic benchmarking tools. With a greater understanding of the component elements and clear differentiation between constraints and controllable variables, the relevant aspects in developing improvement programs and capital expenditure decisions can be identified

PERFORMANCE GRADIENTS AND BREAK-EVEN THRESHOLDS

Building on the cost curve concept, it is possible, however, to return to the chart to consider in more detail the probable impact of any proposed investment, and to determine the effect that this will have on shipyards with different current operating characteristics.

Performance Gradient

For a given yard, an analysis of the expected changes in operating costs and productivity, resulting from a proposed development, allows a second discrete point to be plotted on the cost curves indicating the new performance of the business following implementation of the technology. By joining these two points a gradient indicating which direction the yard's

performance will move on the chart is achieved as shown in Figure 3.

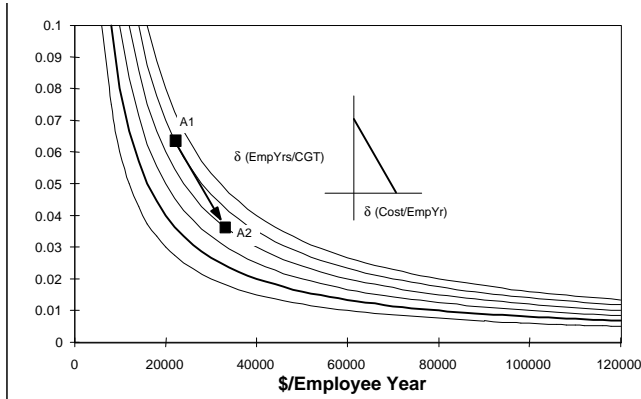


Figure 3 The performance gradient

To understand the relevance of this gradient to decision planning, it is necessary to understand what it represents. For any given technology investment, e.g. the automation of a process, the productivity per employee should be increased, but the costs per employee will also be higher as there will be increased overhead costs and a reduction in the number of employees. The increased productivity is calculated in terms of the reduction in employee years per CGT, and the increase in costs is calculated in terms of the net increase in costs per employee year. These are the two elements of the gradient shown in Figure 3. This 'performance gradient' can be calculated for the investment by dividing the expected change in employee years per CGT by the expected change in costs per employee year. Expressed mathematically:

$$\text{Performance Gradient} = \frac{\delta(\text{EY/CGT})}{\delta(\text{Cost/EY})} \quad (1)$$

Break-even Threshold

When a calculated performance gradient is plotted on the chart, it may either indicate that overall cost competitiveness of a shipyard will improve, as indicated for yard B in Figure 4, or that the performance will deteriorate, as for yard A. These two yards are shown as operating on the same cost curve, and so there must be a point between yards A and B at which the investment ceases to be detrimental, and becomes profitable. This is when the gradient line is tangential to the cost curve, and this point is called the break-even threshold for investment in yard C.

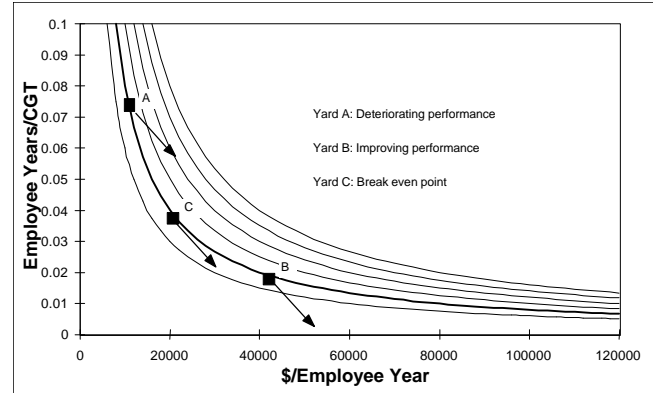


Figure 4 The breakeven threshold

Thus, the introduction of new technology that improves productivity does not guarantee that the overall performance of the yard will be improved. The illustration in Figure 5 shows the effect of different performance improvement gradients to different yards. In the case of Yard A, the gradient for Option 1 moves the shipyard onto lower cost curves representing improved performance (i.e. lower \$ per CGT). However, the performance gradient for Option 2 is such that the yard moves in the wrong direction and there is a net increase in the \$/CGT costs (i.e. its new position would be on a higher cost curve than it was prior to the investment). The situation is different, however, for Yard B when both options move the yard in the right direction representing improved performance.

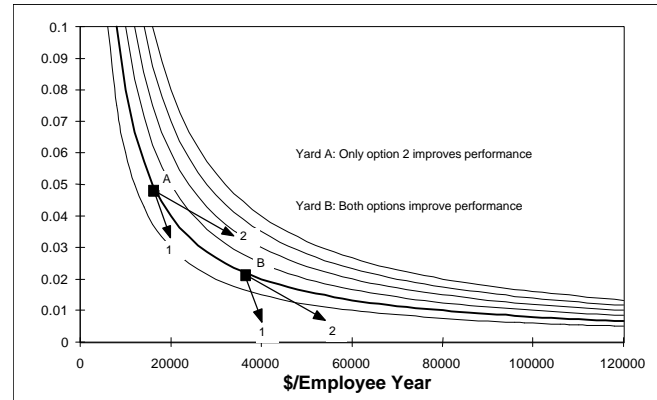


Figure 5 The impact of new technology on performance

For any yard therefore, the break-even threshold can be established for its current position on the cost curves, expressed in terms of the gradient of the tangent to the cost curve. Figure 6 shows a series of radial lines overlaid on the cost curves denoting the gradient of the break-even threshold for different points on the cost curves. Using these lines the break-even threshold for any yard can be established by simple interpolation.

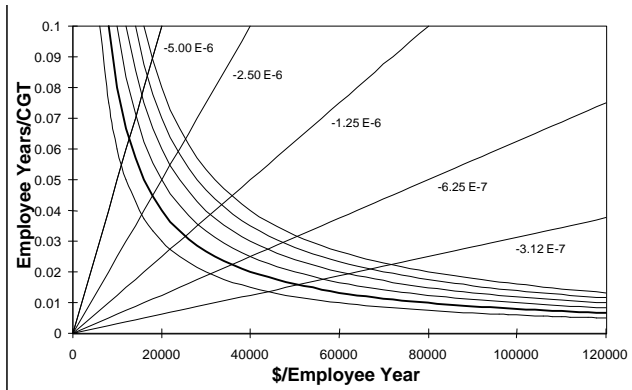


Figure 6 Determining the breakeven threshold

TECHNOLOGY COST ACCOUNTING

The technology audit reflects the result of investment in technology by a specific shipyard, associated with which is an investment cost. The investment cost in itself drives up the cost base of the shipyard and hence the cost per employee year parameter (X axis) of the output cost on the cost curves. To justify investment, these increased costs must be exceeded by the associated savings from the implementation of the technology - predominantly the reduced labor costs resulting from improved productivity.

The assessment of technology investment costs, both new and existing, is however often influenced by the traditional financial accounting treatments. In the case of investment in hardware, these costs are often capitalized and are reflected on the profit and loss account through depreciation provisions, thus diluting the impact on annual overheads in accordance with the depreciation term and method adopted. These choices are generally determined by the applicable taxation laws rather than an assessment of the economic life and benefit profile of the technology concerned. Given the major costs of many hardware investments, such as panel lines, paint cells and robotics, the choice between 5 or 10 year depreciation terms, and straight line versus sum-of-the-years depreciation method, can totally alter the economic appraisal as shown in Figure 7.

This phenomenon, along with the 'feel good factor' associated with the shiny new equipment and facilities of hardware investment, have combined to favor hard rather than soft technology options and probably lie behind much of the past sub-optimum investment in upgrading shipyard facilities. However, it is now generally accepted that much investment in hard technological solutions is less beneficial than soft technology options which may need, in any case, to be in place before the full benefits of some of the more advanced hard technology improvements can be realized. A yard registering a high score on the technology audit, whilst lying on a uncompetitively high cost curve, may well be reaping the misery of inappropriate investment in the past for which it will pay the penance of wearing an economic millstone for some time. In such instances the productivity hurdles for that business to

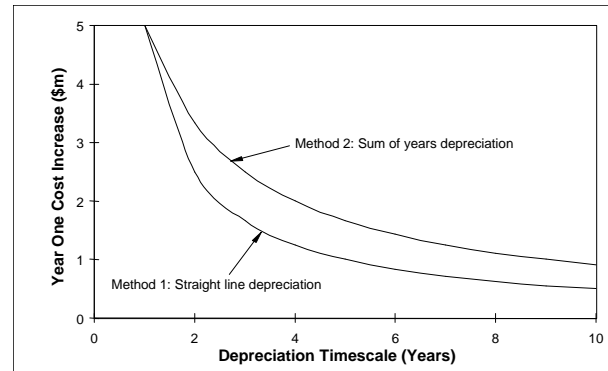


Figure 7 The impact of alternative depreciation methods

operate competitively are higher than they might have been.

In understanding these potential distortions to the treatment of technology costs and in assessing the cost benefit profile and timescale of both hard and soft technological options based upon operational rather than accounting criteria, more effective deployment of investment funds can be achieved.

STRATEGY DEVELOPMENT

Competitive benchmarking may be used to assist a shipyard management team in establishing the target performance for the business and, used in conjunction with the other concepts discussed in this paper, to develop a program of initiatives to support the achievement of this.

Target performance

In developing a shipyard's improvement strategy, the measure of overall performance measured in \$ per CGT becomes a very powerful tool to:

- establish the break-even rate to match the operating performance with market price levels,
- target the optimum market sector in terms of product mix and competitors,
- establish the performance improvement need for competitive operation,
- identify the impact of rising labor costs and throughput variations, or
- establish sensitivity to exchange rate variations against the dollar.

Target Marketing Once a shipyard has established its current position in terms of cost per unit of output measured as \$ per CGT, basic viability (the first concern in any commercial environment) can be ascertained by considering this cost performance with the added value element (i.e. excluding direct material costs) of the market selling rate for its current product range. Using the 'Macawber' principle [10] if this rate is lower than the cost of production, the result is commercial 'misery'. In such circumstances either the business must improve its

performance to survive or must move into a sector of the market commanding a higher selling rate, and hence added value element, measured in terms of \$ per CGT.

Figure 8 shows how the added value component for different ship types can be plotted against the current operating performance of the business. Where the market rate is above the line the shipyard can operate effectively. However, for those product types falling below the line, the business will incur losses. Overall profitability for an existing orderbook or planned product mix can then be determined based upon a weighted average (by value) and compared with the current operating performance.

Within a chosen market sector, a shipyard can compare its performance against its competitors in that

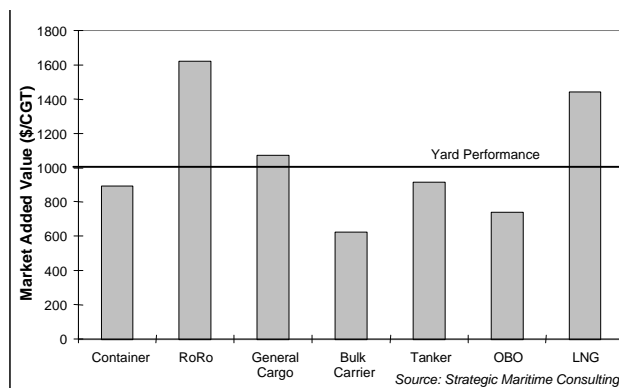


Figure 8 Target market identification

sector using the cost curves to assess not only the potential to improve profitability, but also, in the current position of supply side over capacity, the ability of the shipyard to win sufficient orders to effectively utilize its resources.

This approach has been developed and applied to establish an effective marketing strategy for individual yards [11]. It has also been used to assess the commercial viability and strategic implications of the transfer from naval to merchant shipbuilding considered by many US yards, and the effective market sectors for the higher cost Western European shipbuilders.

Throughput Volumes The volatility of world shipbuilding demand and the relatively high barriers to market entry and exit have produced a market with an elastic demand curve and a relatively inelastic supply curve. The resulting imbalance between supply and demand leads to periods of supply side overcapacity which have been exacerbated by capacity additions in certain areas of the world. The intense competition arising from this has not only driven prices down, it has also meant that many yards are finding it increasingly difficult to fully utilize their resources, either physical or human, and are looking at reduced throughput volumes for the future.

The economies of scale are such that a variation in throughput volumes, measured in CGT, will have a marked effect on the overall performance in terms of cost per unit of output. For a given market rate, the throughput volume at

which the cost of production equals the market rate can be assessed to ascertain the break-even point. Alternatively, for an anticipated throughput volume, the overall performance can be established to achieve break-even or a target level of profitability.

Labor Rates Shipyard labor rates are rising in most shipbuilding nations, especially in some of the Far East and East European countries. This is also happening in developing nations where the employment cost represent a high proportion of total operating cost. To maintain competitiveness, these rises need to be matched by productivity gains. Target levels of productivity in terms of employee years per CGT can be established for various labor rate scenarios, establishing improvement targets over the period of a strategic plan.

Exchange Rates Similarly, the effect of exchange rate variations on the cost per unit output can be ascertained to establish the sensitivity of the business to such external factors. This is of particular importance where long orderbooks exist, and for developing countries where their strengthening economies combine to push up exchange rates and labor rates thus demanding significant increases in productivity to maintain competitiveness.

Based upon this information a target performance level can be established, in terms of the desired cost per unit of output expressed in \$ per CGT. Comparing this with the current performance established in accordance with the principles explained earlier, the improvement gap can be calculated.

Development Program

Having quantified the required improvement in the form of a target performance level, the method of achieving this improvement needs to be established in terms of where the improvement initiatives will be focused to achieve maximum benefit.

In implementing technology, the objective is to raise the level of technological sophistication in a uniform manner across a business. Islands of higher technology in an otherwise less sophisticated environment generally do not reach their full potential. Weak points in the technology can dissipate or dilute the benefits of overall investment in the same way that bottlenecks in the production process throttle output.

Analysis of the technology audit results determines how uniformly technological progress has been made and highlights any low points or areas of imbalance. In such circumstances, a priority of the development program should be to address these imbalances to restore the uniformity thereby eliminating the so called islands of automation [12].

Historically, investment in technology has often concentrated on upgrading the hardware and facilities of the shipyard whilst the investment in upgrading and improving the sophistication of the management processes, organization and systems has lagged behind. The technology audit demonstrates this clearly in terms of a lower ratings in the relevant modules. In such circumstances the focus of the development program should lie in these areas.

In other instances, a technology audit shows that past investment in technology has been concentrated in certain

aspects of the business, for example in steelwork, where a high level of mechanization and automation has become the norm. However, if this has left the outfit and construction aspects lagging behind, then the full benefit of the investment is likely to be dissipated in the latter stages of the shipbuilding process. The potential for improvement through investment in appropriate, hardware or soft technological initiatives will be greater in these areas. In such instances, emphasis should be placed on considering projects which would lift the level of technological sophistication in the lower technology areas in preference to further investment in the already leading technology aspects of the business.

For certain aspects of the shipbuilding process, such as coatings technology, further assistance in identifying potential options for development is available, where specialized audits have been developed to focus on critical areas or bottlenecks [13].

Where a balanced development of technology is achieved, a shipyard tends to reap synergic benefits over and above the direct benefits of the investment calculated in the performance gradient approach.

Evaluating options Using these concepts, a shipyard management establishes a range of possible improvement initiatives, each requiring different implementation resources and resulting in varying productivity improvements. For each such initiative, the performance gradient can be calculated demonstrating the direction in which each would move the overall performance of the business on the cost curves. At this stage the treatment of technology costs becomes critical, requiring careful assessment of the economic benefit profile of the initiative to determine over what period of time and with what profile, the capital or implementation costs of the initiative should be spread.

Where the performance gradient is steeper or equal to the break-even gradient, the initiative has a beneficial effect on the overall cost per unit of output of the yard, moving the business onto a lower cost curve. However where the gradient is flatter than the break-even gradient, implementation has a detrimental effect on the business and would serve to move the yard onto a higher cost curve, thus making it less competitive.

In this fashion, the initiatives can be ranked in terms of their performance gradients to establish those which would generate the greatest benefit to the business. This information can then be used in conjunction with the results of the technology audit, and the capital or financing constraints to establish a development program for the business.

In appraising individual initiatives in this fashion, projects are prioritized on a pure cost benefit basis. Simplistically this assumes that investment capital is readily available. However, in practice, shipyards have financial and other constraints, and the situation may be more complex requiring a balance between a number of factors.

In any investment decision, the key criteria for shipyard management are likely to be financing and employment. There is a finite limit to the money available to finance technological improvements and these improvements will result, primarily, in a reduction in the demand for labor and hence a reduction in employment levels. In high technology yards, the driving force

is generally the difficulty in recruiting. In these yards investment and capital financing is more readily available, and the improvement projects can be selected based upon these criteria.

However in developing countries, where labor costs are beginning to rise, the availability of capital funds to finance the productivity improvement necessary to maintain and improve the costs per unit of output are often severely restricted and may depend on government financing. Similarly the shedding of labor in such situations is likely to be an emotive and political issue bringing with it the possibility of major industrial relations issues or political intervention. The issue facing the yard management is one of balancing the availability of finance with an acceptable level of job loss, e.g. through early retirement programs whilst attaining competitive \$ per CGT operating performance as dictated by the market price selling level.

The cost structure for an individual yard, reflecting its current position on the cost curves, can be used to generate a series of curves as shown in Figure 9 plotting the reduction in jobs (Y axis) against the increase in annual capital cost for a variety of \$/CGT improvement levels. Having assessed the economic benefit lifetime of various improvement options, the increased annual overhead costs can be determined. These curves can be used to identify and prioritize options that can balance these twin criteria to help meet specific improvement targets.

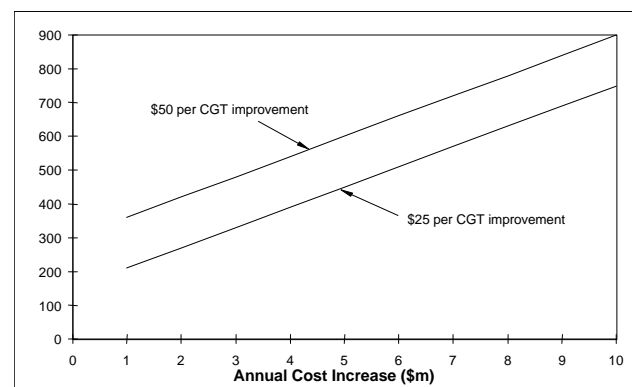


Figure 9 Constraints on development strategies

The overall impact of a group of initiatives implemented over a specific time period, can be calculated, to predict the cost per unit output of the business following implementation of these initiatives.

CONCLUSION

In relation to soft and hard aspects of technological development, it is unlikely that the full benefit of hardware investment can be obtained whilst the management and operational processes are sub optimal. Given the relatively high costs of hardware investment, improvement in the operating processes and systems generally offers low technology yards a better return for their investment.

Thus it would appear that a basic strategy for performance

improvement requires a balance between hardware investment and soft technological investment. It should follow a development pattern that uniformly raises the technological sophistication of the yard in response to the changes in the business structure and economic environment. On a commercial basis, the development program would not seek technological development as an objective, rather as a means to maintain or improve the cost per unit output as indicated by progress on the cost curve diagram.

The following examples, provide an interesting perspective on how different development strategies and economic circumstances have impacted on the trends in the current world shipbuilding capacity.

- Swedish shipbuilders backed up development in technology with excellent systems. However the rate at which labor cost increased meant considerable investment in hardware which at that time (mid 1970s) proved prohibitively expensive, or simply not available. They were unable to remain competitive.
- In the UK., some of the most modern facilities and hardware were introduced in the mid 1970s but were not supported by the appropriate investment in organization and systems. When this finally occurred in the early 1980s it was already too late.
- In Japan effort was placed on developing systems to maximize use of the hardware in place, and it has often been commented on since that time that Japanese yards are rarely equipped with the latest hardware technology, but often they have achieved a remarkable balance between systems and hardware investment.

Historically the development of shipyard technology has been a mix of hardware improvement and development of soft technological aspects with most yards on the benchmark iso-cost curve being at different stages of this cycle. Effective future development strategies must be set against the demands of the market and capabilities of competitor yards and need to be based upon a clear understanding of a shipyard's current position and the impact on the proposed technological improvements on this.

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